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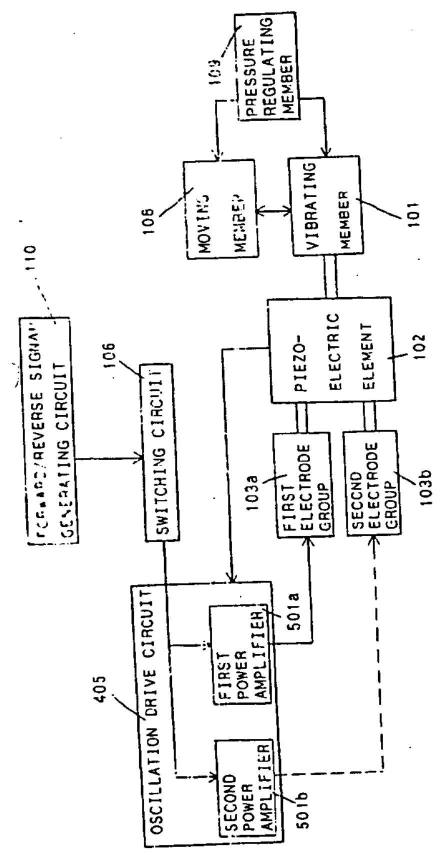
(54) **Ultrasonic motor and electronic apparatus provided with ultrasonic motor**

(57) An ultrasonic motor which can perform forward/reverse control with a simple driving system and also has high environmental reliability. At least two sets of electrode groups (103a, 103b) each comprising plural electrodes are formed on the surface of a piezoelectric element (102), and there are provided an oscillation drive circuit (405) which is provided with at least two power amplifiers (501a, 501b) whose output terminals are connected to the respective electrode groups and which excitationally drive the respective electrode groups independently of each other, and a switching circuit (106) for selecting at least one of the power amplifiers of the oscillation drive circuit on the basis of the output signal of a forward/reverse signal generating means (110) to set the rotational direction of a moving member (108).

FIG. 1



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Description

The present invention relates to an ultrasonic motor for frictionally driving a moving member with vibrational wave produced in the vibrating member to which a piezoelectric element is bonded, and an electronic apparatus provided with the ultrasonic motor.

There has been hitherto known an ultrasonic motor for driving a moving member contacted with a vibrating member under predetermined pressure by using travelling wave which is produced in the vibrating member by applying a predetermined high-frequency voltage to a piezoelectric element which is bonded to the vibrating member.

For example. such a conventional structure of an ultrasonic motor is disclosed in Japanese Laid-open Patent JP-A-58-148682 (1983).

Moreover, in a field of an electronic apparatus, especially of an electronic timepiece, having a mechanical actuator, a magnetic motor is generally provided for such an apparatus or timepiece. Fig. 15 is a sectional view of a conventional analog type electronic watch provided with a magnetic stepping motor. A stator 53 is disposed on the upper surface of a base plate 40, and a coil core 52 is screwed to the upper surface of the stator 53 so as to be brought into contact with the upper surface of the stator 53. A coil wire 51a is wound around the coil core 52, and it is connected to a driving circuit (not shown).

A rotor 54 is rotationally installed into a rotor hole 53a of the stator 53, and the rotation of the rotor 54 is transmitted to a fifth wheel 55. a second hand wheel 44, a third wheel 43, a minute hand wheel 42, a minute wheel (not shown), and an hour hand wheel 45.

When a predetermined voltage is applied to the coil wire 51a at a constant interval, the rotor 54 is rotated by a magnetic force of the stator 53, and "hour", "minute" and "second" are indicated with an hour hand 32 fixed to the hour hand wheel 45, a minute hand 33 fixed to the minute hand wheel 42, and a second hand 34 fixed to the second hand wheel 44, respectively.

However, in order to rotationally drive the moving member in a conventional travelling wave type ultrasonic motor, it is required that two high-frequency voltages having different phases are applied to the piezoelectric element to produce vibration of travelling wave in the vibrating member, and thus two driving circuits are required. Furthermore, since vibrational characteristics of the vibrating member vary in accordance with variation of an environmental temperature or a driving voltage, it is required to provide a complicated driving circuit which can perform a driving operation while conforming driving parameters such as the applied voltage, the phase, etc. to an environmental variation at all times.

In addition, in the travelling wave type ultrasonic motor which performs the driving operation by applying two high-frequency voltages having different phase, the direction of the rotation is switched by varying the phase of the two high-frequency voltages, so that the switching operation of forward/reverse rotation is cumbersome and the driving circuit is also complicated.

As described above, there has been a problem that the driving circuit is very complicated although the ultrasonic motor has a simple structure, and thus there has been also a problem that application to an electronic apparatus, etc. is difficult.

It is an object of the present invention to provide an ultrasonic motor which can perform a forward/reverse rotation control by using a simple driving system, and has high environmental reliability.

It is another object of the present invention to provide an electronic apparatus provided with an ultrasonic motor having small size and low cost by using a simplified driving system.

In order to achieve the above objects this invention provides an ultrasonic motor which is provided with a vibrating member having a piezoelectric element bonded thereon, and which serves to frictionally drive a moving member with vibrational wave which is produced in the vibrating member through a stretching and contracting motion of the piezoelectric element, characterised by comprising:

a piezoelectric element having at least two sets of electrode groups which each comprise plural electrodes and are formed on a surface of said piezoelectric element;
an oscillation drive circuit having at least two power amplifiers, each of which has an output terminal connected to one of said at least two sets of electrode groups formed on said piezoelectric element, and which excitationally drives each of said electrode groups independently;
a forward/reverse signal generating means for producing a forward/reverse signal to set a rotational direction of said moving member; and
a switching circuit for selecting at least one of said at least two power amplifiers of said oscillation drive circuit to drive at least one of said electrode at least two groups on the basis of the output signal from said forward/reverse signal generating means.

The ultrasonic motor described above is capable of performing a forward/reverse rotation control with a simple driving system and has high environmental reliability.

Embodiments of the invention will now be described, by way of example only, with reference to the accompanying diagrammatic figures, in which;

Fig. 1 is a block diagram showing an example of the typical construction of an ultrasonic motor according to the present invention;
Fig. 2 is an actual circuit diagram showing a first embodiment of the ultrasonic motor according to the present invention;

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Fig. 3 is a reference diagram to explain features of the ultrasonic motor according to the present invention:

Fig. 4 is a plan view showing a vibrating member of a second embodiment of the ultrasonic motor according to the present invention;

Fig. 5 is a sectional view showing the vibrating member of the second embodiment of the ultrasonic motor according to the present invention;

Fig. 6 is a sectional view showing the ultrasonic motor of the second embodiment of the present invention:

Fig. 7 is a plan view showing a vibrating member of a third embodiment of the ultrasonic motor according to the present invention;

Fig. 8 is a sectional view showing the vibrating member of the third embodiment of the ultrasonic motor according to the present invention;

Fig. 9 is a diagram showing an electrode construction on the surface of a piezoelectric element of a fourth embodiment of the ultrasonic motor according to the present invention;

Fig. 10 is a diagram showing an electrode construction on the back surface of the piezoelectric element of the fourth embodiment of the ultrasonic motor according to the present invention;

Fig. 11 is a block diagram showing a fifth embodiment of the ultrasonic motor according to the present invention;

Fig. 12 is a sectional view showing a sixth embodiment of the ultrasonic motor according to the present invention:

Fig. 13 is a sectional view showing a seventh embodiment of a vibration generating apparatus using the ultrasonic motor according to the present invention:

Fig. 14 is a sectional view showing an eighth embodiment of an analog type electronic watch equipped with the ultrasonic motor according to the present invention; and

Fig. 15 is a sectional view showing a conventional analog type electronic watch.

Fig. 1 is a block diagram showing an example of the typical construction of an ultrasonic motor according to the present invention.

In Fig. 1, two sets of electrode groups 103a, 103b each comprising plural electrodes are formed on the surface of the piezoelectric element 102. The oscillation drive circuit 405 has two power amplifiers 501a, 501b, and the output terminals of the two power amplifiers 501a, 501b are connected to the two sets of electrode groups 103a, 103b formed on the surface of the piezoelectric element 102 to excitationally drive the respective electrode groups independently of each other. The forward/reverse signal generating circuit 110 outputs to the switching circuit 106 a forward/reverse signal for setting the rotational direction of a moving member 108. The output terminals of the switching circuit 106 are connected to the two power amplifiers 501a, 501b of the oscillation drive circuit 405 to select one of the two power amplifiers 501a, 501b on the basis of the output signal of the forward/reverse signal generating circuit 110. The rotational direction of the moving member 108 is reversed by changing the power amplifier to be operated on the basis of the output signal from the switching circuit 106.

The moving member 108 is disposed so as to be brought into contact with a vibrating member 101 under a predetermined pressure by a pressure regulating member 109.

In the conceptual construction described above, three or more sets of electrode groups and three or more power amplifiers can be applied under the scope of the present invent ion.

Embodiments according to the present invention will be hereunder described with the reference to the drawings.

(1) First embodiment

Fig. 2 shows an actual circuit construction of a first embodiment of an ultrasonic motor according to the present invention.

A piezoelectric element 102 having two sets of electrode groups 103a and 103b each comprising plural electrodes which are formed on one flat surface of the piezoelectric element 102 is bonded to a vibrating member 101 by an adhesive or other means. An oscillation drive circuit 405 is constructed by including the vibrating member 101 to which the piezoelectric element 102 is bonded. A pre-amplifier 502 using a tri-state inverter takes a role of an inverting amplifier for inversely amplifying an electrical signal which is excitation information input from the vibrating member 101 or an electrode 103c formed on the opposite surface to the surface of the piezoelectric element 102 on which the two sets of electrode groups 103a and 103b are formed. Namely, the vibrating member 101 bonded with the piezoelectric element 102 thereon acts as a mechanical resonator for an oscillation circuit in this case. Therefore, the oscillation drive circuit 405 has a feature of a self-exited oscillation circuit on the basis of a resonant characteristic of the vibrating member 101. A resistor 503 is connected to the pre-amplifier 502 in parallel, and serves to stabilise an operating point of the pre-amplifier 502.

The output terminal of the pre-amplifier 502 is connected to the input terminals of two power amplifiers 501a and 501b using tri-state buffers through a resistor 504. The respective output terminals of the two power amplifiers 501a and 501b are connected to the respective two sets of electrode groups 103a and 103b which are formed on the one flat surface of the piezoelectric element 102. Respective one ends of two capacitors 505 and 506 are connected to the input terminal of the pre-amplifier 502 and to the output terminal of the pre-

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amplifier 502 through the resistor 504, and the other ends thereof are grounded whereby a phase adjustment in the oscillation drive circuit 405 is performed.

It is very effective to obtain a high motive power output from the ultrasonic motor when the two power amplifiers 501a and 501b are disposed just before the two sets of electrode groups 103a and 103b formed on the piezoelectric element 102. the capacitors 505 and 506 are connected to the input terminal and the output terminal of the pre-amplifier 502 for the purpose of phase adjustment and interruption of direct current and the piezoelectric element 102 basically serves as a capacitive load.

Each of the pre-amplifier 502 and the two power amplifiers 501a and 501b has a control terminal as well as the input and output terminals and designed in such a tri-state structure that the output terminal can be set to a high impedance state in accordance with a signal to be input to the control terminal.

A forward/reverse signal generating circuit 110 outputs to a switching circuit 106 a forward/reverse signal for setting a rotational direction of the ultrasonic motor. The output terminals of the switching circuit 106 are connected to the two power amplifiers 501a and 501b of the oscillation drive circuit 405 and the control terminal of the pre-amplifier 502 respectively, and on the basis of the output signals of the forward/reverse signal generating circuit 110, one of the two power amplifiers 501a and 501b is controlled to serve as a normal buffer while the output terminal of the other power amplifier is kept in a high impedance state to be disabled.

The vibrating member 101 is driven by the power amplifier which is selected on the basis of the output signals of the switching circuit 106 and functions as the normal buffer. The vibrating member 101 is driven by only the power amplifier which is permitted to function as the normal buffer by the switching circuit 106, and the rotational direction of the ultrasonic motor is reversed when the power amplifier which is permitted to function as the normal buffer is switched by the switching circuit 106.

In such an ultrasonic motor that the rotational direction is switched by properly using the two sets of electrode groups 103a and 103b formed on the piezoelectric element 102, it may be considered to use a switch 224 such as an analog switch, as shown in Fig. 3, in order to selectively install and use any one of the two sets of electrode groups 103a and 103b in the oscillation drive circuit 405. However, the switch 224 has no little resistance components, and thus it causes variation of oscillation drive frequency, voltage level, etc. in the vibrating member 101 serving as a capacitive load due to phase shift, so that the loss of the output of the motor is increased.

As compared with the system of switching the electrode groups 103a and 103b by the analog switch 224 as shown in Fig. 3, the structure that the two power amplifiers 501a and 501b are independently provided to the respective two sets of electrode groups 103a and 103b has an advantage that various problems occurring due to the resistance components of the switch can be overcome, and it contributes to the output of the ultrasonic motor.

Further, in the first embodiment, the output terminal of the pre-amplifier 502 can be set to a high-impedance state on the basis of the output signal from the switching circuit 106 which is output on the basis of the output of the forward-reverse signal generating circuit 110, and when the pre-amplifier 502 is disabled, both the two power amplifiers 501a and 501b are disabled and thus the ultrasonic motor can be stopped.

As described above, the switching operation between the forward rotation and the reverse rotation can be easily and accurately performed, so that there can be obtained an advantage that a control system containing a drive circuit can be made simple in construction when this embodiment is applied to a positioning system or the like. Further, when this embodiment is applied to an electronic apparatus to which a lot of restriction in size is imposed, particularly when it is used as a driving source for a wristwatch, the forward/reverse operation can be performed in a simple manner using only one motor, and this is very advantageous in size and cost.

(2) Second Embodiment

Figs. 4 and 5 are plan and sectional views, respectively, of a second embodiment of the ultrasonic motor according to the present invention, and the same construction of the oscillation drive circuit as the first embodiment shown in Fig. 2 is used.

A disc-shaped piezoelectric element 102 is bonded to the flat surface of a disc-shaped vibrating member 101 by an adhesive, thin film forming, or other means. The ultrasonic motor of this embodiment excites standing waves of two wave numbers in a circumferential direction in the vibrating member 101 to drive the vibrating member 101.

Eight-segmented electrodes whose number is equal to four times of the number of the waves are alternately subjected to polarisation treatments (+) and (-) so that alternate electrodes form each of the first electrode group 103a and the second electrode group 103b in the circumferential direction on one flat surface of the piezoelectric element 102 as shown in the figures. The first electrode group 103a comprises electrodes a1, a2, a3 and a4, and the respective electrodes are short-circuited to one another by a first circuit means 104a. The second electrode group 103b comprises electrodes b1, b2, b3 and b4, and the respective electrodes are short circuited to one another by a second circuit means 104b. In the figures, (+) and (-) represent the direction of the polarisation treatment, and positive electric field and negative electric field are respectively applied to the bonding surface side of the piezoelectric element 102 which is bonded to the vibrating member 101 to perform

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the respective polarisation treatments.

In place of the above disc-shaped piezoelectric element on which the electrode is segmented at substantially regular intervals, plural sectorial piezoelectric elements may be attached to the flat surface of the vibrating member in a disc shape.

Projections 107 for transmitting motive power are provided at the positions adjacent to alternate boundary portions of the respective electrodes.

In this case, a high-frequency voltage produced by the oscillation drive circuit 405 is applied to either one of the two electrode groups 103a and 103b to drive the vibrating member 101. The rotational direction of the ultrasonic motor is switched in accordance with the selection of the electrode group which drives the vibrating member 101.

Fig. 6 is a sectional view showing the second embodiment of the ultrasonic motor of the present invention.

A centre shaft 202 is fixed to a fixed stand 201. The vibrating member 101 on which the piezoelectric element 102 is adhered is fixedly supported in the vicinity of the central portion by the centre shaft 202 so as to be integral with the fixed stand 201. The moving member 108 is rotatably guided by the centre shaft 202, and it is brought into contact with the vibrating member 101 under a predetermined pressure through the projections 107 by a pressure regulating spring 109 having one end fixedly mounted to the external (not shown).

(3) Third Embodiment

Figs. 7 and 8 are plan and sectional views, respectively, showing a third embodiment of the ultrasonic motor according to the present invention, and only the points different from the vibrating member used in the second embodiment will be described.

The same construction of the two sets of electrode groups 103a and 103b formed on one surface of the piezoelectric element 102 as in the second embodiment may be applied.

Projections 107 which serve to transmit the motive power and having the same shape as in the second embodiment are provided at the positions adjacent to alternate boundary portions of the respective electrodes, and further shorter projections 100 which have the same shape as the projections 107 are provided at the positions adjacent to the other alternate boundary portions of the respective electrodes arranged between the positions at which the projections 107 are provided.

The projections 107 are provided to transmit the motive power to the moving member 108. However, the shorter projections 100 having the same shape as the projections 107 do not transmit the motive power to the moving member 108, and are arranged on the surface of the vibrating member 101 so that the plural projections formed on the surface of the vibrating member 101 are in an excellently balanced arrangement. Therefore, the shorter projections 100 contribute to adjust a vibration state.

Further, in this embodiment, the shorter projections 100 which do not transmit the motive power and are provided to adjust the vibration state of the vibrating member 101 are disposed at the positions adjacent to the boundary portions between the respective projections 107. However, shorter projections whose number is equal to an odd number such as three, five or the like may be provided between the respective projections 107, or an arcuate projection having large width may be provided in the circumferential direction between the projections 107.

(4) Fourth Embodiment

Figs. 9 and 10 show the electrode construction which is formed on the front and back surfaces, respectively, of the piezoelectric element bonded to the vibrating member of a fourth embodiment of the ultrasonic motor according to the present invention.

In the ultrasonic motor of this embodiment, in order to excite standing waves of three wave numbers in the circumferential direction and drive the vibrating member 101, 12-segmented electrodes whose number is equal to four times of the number of the waves are formed in the circumferential direction on one flat surface of the piezoelectric element 102, and projections 107 for transmitting the motive power to the moving member 108 are provided at the positions of alternate electrode boundary lines on the surface of the vibrating member 101 opposite the surface to which the piezoelectric element 102 is bonded. The number of the projections is equal to six.

Connection is required to be made to sets of alternate electrodes to construct the two sets of electrode groups 103a and 103b by using the 12-segmented electrodes. However, in order to satisfy this requirement, all the 12-segmented electrodes must be soldered or welded, and a lead wiring connection may cause leakage of the vibration or increase of loss, so that some troubles may occur in a manufacturing process.

Therefore, the first electrode group 103a and the second electrode group 103b are formed as follows: the 12-segmented electrodes are formed on one surface of the piezoelectric element 102 while an electrode 103c is formed on the other whole surface by a thin film forming means such as vapour deposition, sputtering, printing or the like, then performing a polarisation treatment shown in Fig. 9, and then performing the connection on the two interleaved sets of alternate electrodes of the 12-segmented electrodes in the same thin film forming means as described above again. By forming the two sets of electrode groups 103a and 103b as described above, the number of lead wires which are required to apply a driving signal can be reduced to only two regardless of the wave numbers produced in a circumferential direction on the piezoelectric element 102.

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Further, the piezoelectric element on which the two electrode groups are formed by the thin film forming means as described above may be applied to the ultrasonic motor of the previously-described embodiment.

(5) Fifth Embodiment

Fig. 11 is a block diagram showing a fifth embodiment of the ultrasonic motor of the present invention.

The same support structure as the second embodiment shown in Fig. 6 is used for the vibrating member 101, the piezoelectric element 102 and the moving member 108.

The oscillation drive circuit 405 performs power amplification and phase adjustment on excitation information of the vibrating member which is obtained from the piezoelectric element 102 bonded to the vibrating member 101, and applies a high-frequency voltage to any one of the first electrode group 103a which are short-circuited by the first circuit means 104a shown in Fig. 5 or the second electrode group 103b which is short-circuited by the second circuit means 104b shown in Fig. 5. Further, there is provided a switching circuit 106 for switching the electrode group to which the high frequency voltage produced by the oscillation [illegible] 405 is applied, on the basis of the output [illegible] verse signal generating circuit 110 to [illegible] reverse signal to set the rotational dire[illegible] sonic motor.

Bending vibrational wave is excite[illegible] member 101 and the piezoelectric [illegible] high frequency voltage produced by th[illegible] circuit 405, whereby the moving mem[illegible] disposed so as to be brought into [illegible] brating member 101 under pressure b[illegible] ulating member 109 such as a coil spr[illegible] or the like is rotationally driven throu[illegible] 107 provided on the vibrating member 101.

A detecting circuit 111 detects rotation information of the moving member 108 through a motive power transmission mechanism 205 such as a gear or friction wheel or the like, and on the basis of the detection signal of the detecting circuit 111, a motor control circuit 112 adjusts the oscillation drive circuit 405 to determine the driving state of the ultrasonic motor.

In this embodiment, the rotation information of the moving member 108 is detected through the motive power transmission mechanism 205, however it may be directly detected from the moving member 108.

(6) Sixth Embodiment

Fig. 12 is a sectional view of a sixth embodiment of the ultrasonic motor of the present invention.

A centre shaft 202 is fixed to a fixed stand 201. The piezoelectric element 102 is adhered to the vibrating member 101, and it is fixedly supported in the vicinity of the centre portion by the centre shaft 202 so as to be integral with the fixed stand 201. The moving member 108 has an output shaft 204 and a motive power transmission mechanism such as a gear or a friction wheel (not shown) to transmit torque from the output shaft.

The moving member 108 is brought into contact with the vibrating member 101 under a predetermined pressure by the pressure regulating member 109 so as to be rotatable. Further, in this embodiment, a means of performing electrical conduction to the first electrode group 103a and the second electrode group 103b is achieved by an elastic support member 203 which performs both conduction and support functions and is provided in the neighbourhood of node portions other than the central portion of the vibrating member 101 and the piezoelectric element 102. With this construction, the respective segmented electrodes can be conducted to one another without using a conduction short-circuiting pattern.

(7) Seventh Embodiment

Fig. 13 is a sectional view showing a seventh embodiment of a vibration generating device using the ultrasonic motor according to the present invention.

The different point from the sixth embodiment of the present invention shown in Fig. 12 resides in that an eccentric weight 209 is provided instead of the output shaft. The moving member 108 rotates integrally with the eccentric weight 209. In accordance with wireless information from the external, time information or the like, the moving member 108 and the eccentric weight 209 of the ultrasonic motor are rotated on the basis of a predetermined signal, whereby information is transmitted to an user with vibration.

(8) Eighth Embodiment

Fig. 14 is a sectional view of an eighth embodiment of an analog type electronic watch using the ultrasonic motor of the present invention.

The vibrating member 101 of the above-described embodiments is fixed to a guide pin 302, and the guide pin 302 is fixed to a base plate 301 by a set screw 303. The moving member 108 is brought into contact with the vibrating member 101 through the projections 107 under a predetermined pressure by the pressure regulating member 109, and guided to the tip portion 302a of the guide pin 302 so as to be rotatably mounted.

Through the first circuit means 104a or the second circuit means 104b provided to the electrodes of the piezoelectric element 102, a high-frequency voltage is applied to the piezoelectric element 102 from the oscillation drive circuit (not shown) of the ultrasonic motor which operates in response to a signal output from a time counting circuit (not shown) operating in accordance with a time base signal output from an oscillation source (not shown), whereby the vibrating member 101 is vibrated and thus the moving member 108 is rotated

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at a constant speed through the projections 107.

A moving member gear 108a on the peripheral portion of the moving member 108 drives a second hand wheel 304, and further drives a third wheel 305, a minute hand wheel 306, a minute wheel (not shown) and an hour hand wheel 307, each at constant speed.

If the number of gear teeth of each gear is set to a predetermined value, "hour", "minute" and "second" are indicated by an hour hand 309 fixed to the hour hand wheel 307, a minute hand 310 fixed to the minute hand wheel 306 and a second hand 311 fixed to the second hand wheel 304.

Display of time information can be performed not only by plural wheels and hands, but also by directly affixing pointers or indexes to the moving member 108. These elements can be viewed from a side of a dial 308 or from a side of the pressure regulating member 109 in Fig. 14.

Further, by adjusting the drive signal output from the motor drive circuit to the piezoelectric element 102 through the motor control circuit, the second hand 311 can move intermittently every second or continuously move.

In addition to the time display, calendar display containing information on year, month and day, and display of residual quantity of battery, environmental information, works, etc. can be performed.

According to the ultrasonic motor of this invention as described above, at least two sets of electrode groups each comprising plural electrodes are formed on the surface of the piezoelectric element, and each of the output terminals of at least two power amplifiers of the oscillation drive circuit is connected to each of at least two sets of electrode groups which are formed on the piezoelectric element. The ultrasonic motor comprises forward/reverse signal generating circuit for generating a forward/reverse signal to set the rotational direction of the ultrasonic motor, and a switching circuit for selecting any one of the at least two power amplifiers of the oscillation drive circuit on the basis of the output signal from the forward/reverse signal generating circuit. Therefore, there can be obtained an advantage that the drive system can be made simple and the environmental reliability can be improved.

That is, the forward/reverse switching operation can be easily and accurately performed, so that the control system containing the drive circuit is simple when this invention is applied to a positioning system or the like. Further, when this invention is used as an electronic apparatus having a lot of restriction in size, particularly a driving source for a wristwatch, the forward/reverse operation can be simply performed by only one motor, and this is very convenient in size and cost.

An ultrasonic motor according to the present invention includes pressure regulating means which is disposed so that a moving member is brought into contact with a vibrating member under pressure, a piezoelectric element having at least two sets of electrode groups which comprise plural electrodes and are formed on the surface of the piezoelectric element, an oscillation drive circuit having at least two power amplifiers each of which has an output terminal connected to each of the at least two sets of electrode groups formed on the piezoelectric element, and which excitationally drives each of the electrode groups independently, forward/reverse signal generating means for producing a forward/reverse signal to set a rotational direction of the moving member, and a switching circuit for selecting at least one of said at least the two power amplifiers of the oscillation drive circuit on the basis of the output signal from the forward/reverse signal generating means.

The aforegoing description has been given by way of example only and it will be appreciated by a person skilled in the art that modifications can be made without departing from the scope of the present invention.

Claims

1. An ultrasonic motor which is provided with a vibrating member (101) having a piezoelectric element (102) bonded thereon, and which serves to frictionally drive a moving member (108) with vibrational wave which is produced in the vibrating member through a stretching and contracting motion of the piezoelectric element, characterised by comprising:

    a piezoelectric element having at least two sets of electrode groups (103a, 103b) which each comprise plural electrodes and are formed on a surface of said piezoelectric element;
    an oscillation drive circuit (405) having at least two power amplifiers (501a, 501b), each of which has an output terminal connected to one of said at least two sets of electrode groups formed on said piezoelectric element, and which excitationally drives each of said electrode groups independently;
    a forward/reverse signal generating means (110) for producing a forward/reverse signal to set a rotational direction of said moving member; and
    a switching circuit (106) for selecting at least one of said at least two power amplifiers of said oscillation drive circuit to drive at least one of said at least two electrode groups on the basis of the output signal from said forward/reverse signal generating means.

2. The ultrasonic motor as claimed in claim 1, and further comprising a pressure regulating means (109) disposed so that said moving member is brought into contact with said vibrating member under pressure.

3. The ultrasonic motor as claimed in claim 1 or claim

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2, wherein, the output terminal of the unselected power amplifier of said at least two power amplifiers of said oscillation drive circuit is set to a high impedance.

4. The ultrasonic motor as claimed in any preceding claim, wherein said oscillation drive circuit includes a pre-amplifier (502) which has an input terminal connected to said vibrating member or an electrode (103c) formed on an opposite surface to the surface on which said at least two sets of electrode groups are formed, and has an output terminal connected to the input terminals of said at least two power amplifiers, and wherein one of said pre-amplifier and said two power amplifiers comprises an inverting amplifier.

5. The ultrasonic motor as claimed in any preceding claim, wherein said oscillation drive circuit has a resonance circuit formed of said vibrating member and a capacitor by utilising an inductive property which said vibrating member has in its mechanical resonance state.

6. The ultrasonic motor as claimed in any preceding claim, wherein electrodes (103) are disposed on said piezoelectric element, the number of electrodes being a multiple of 4 and said electrodes being arranged at substantially regular intervals on at least one surface of said piezoelectric element, respective two neighbouring electrodes of said electrodes being paired and subjected to a polarisation treatment so that the polarisation direction of said electrodes is alternately reversed every pair; and

   wherein the motor further comprises first circuit means (104a) and second circuit means (104b) for electrically short-circuiting alternate electrodes to construct said two sets of electrode groups; and
   projections (107) which transmit motive power to said moving member, and are disposed at the positions adjacent to alternate boundary portions of said electrodes disposed on said piezoelectric element.

7. The ultrasonic motor as claimed in any one of claims 1 to 5, wherein electrodes (103) are disposed on said piezoelectric element, the number of electrodes being a multiple of 4 and said electrodes being arranged at substantially regular intervals on at least one surface of said piezoelectric element, respective two neighbouring electrodes of said electrodes being paired and subjected to a polarisation treatment so that the polarisation direction of said electrodes is alternately reversed every pair; and

   wherein the motor further comprises first circuit means (104a) and second circuit means (104b) for electrically short-circuiting alternate electrodes (103) to construct said two sets of electrode groups (103a, 103b);
   projections (107) which transmit motive power to said moving member, and are disposed at the positions adjacent to alternate boundary portions of said electrodes disposed on said piezoelectric elements; and
   shorter projections (100) each of which is disposed between the respective projections (107) to adjust a vibrational state of the vibrating member and designed to be lower in height than said projections (107) so as not to transmit motive power to said moving member.

8. The ultrasonic motor as claimed in any preceding claims, further comprising:

   detecting means (111) for detecting a rotational state of said moving member; and
   a motor control circuit (112) for adjusting said oscillation drive circuit on the basis of the output signal of said detecting means to control the driving of said ultrasonic motor.

9. The ultrasonic motor as claimed in any preceding claim, further comprising an output shaft (204) which is secured to said moving member.

10. An electronic apparatus provided with an ultrasonic motor comprising:

   the ultrasonic motor as claimed in any one of claims 1 to 9; and
   display means (206) for displaying predetermined information on the basis of an operation of said ultrasonic motor.

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FIG. 1

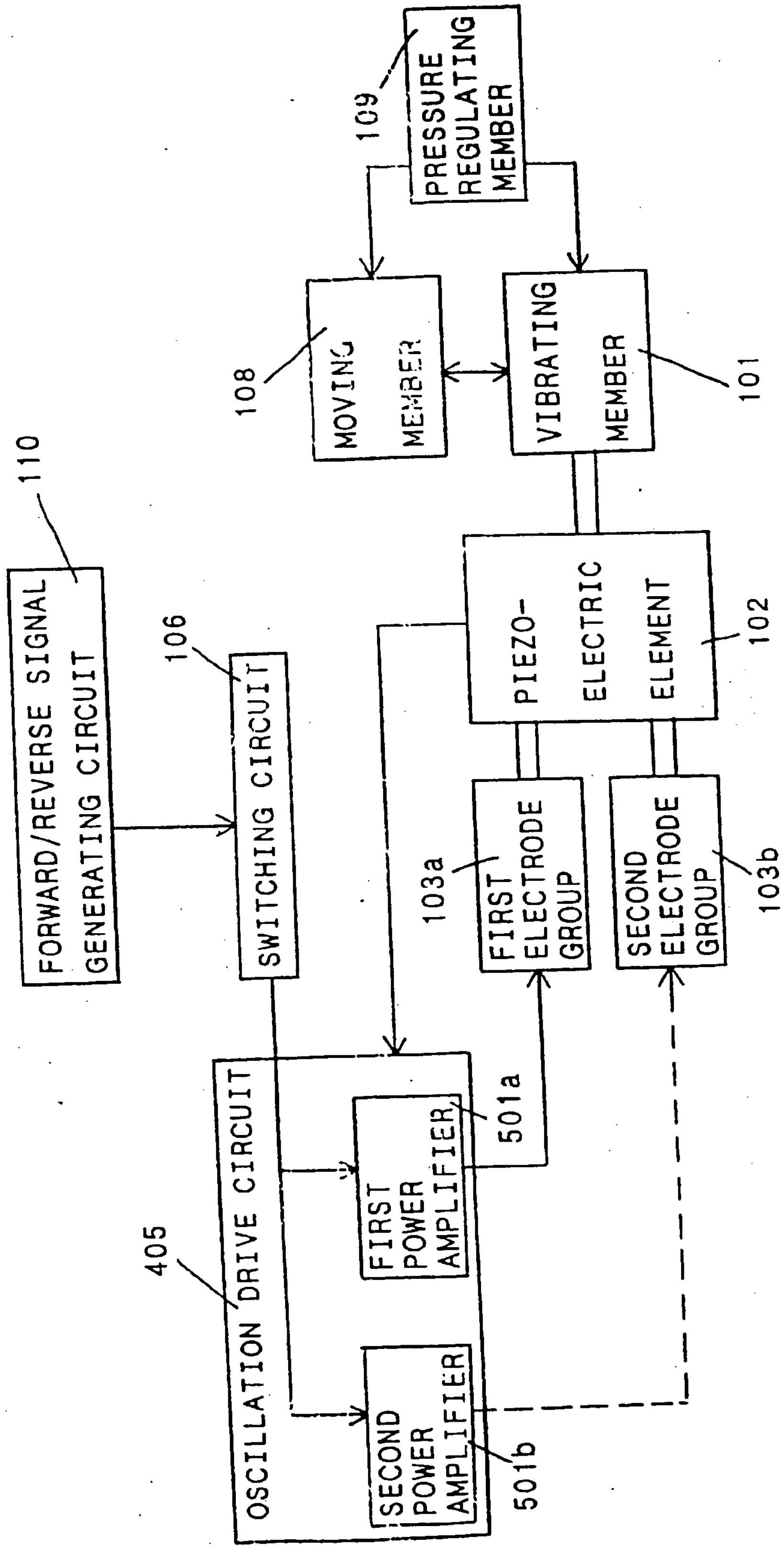

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FIG. 2

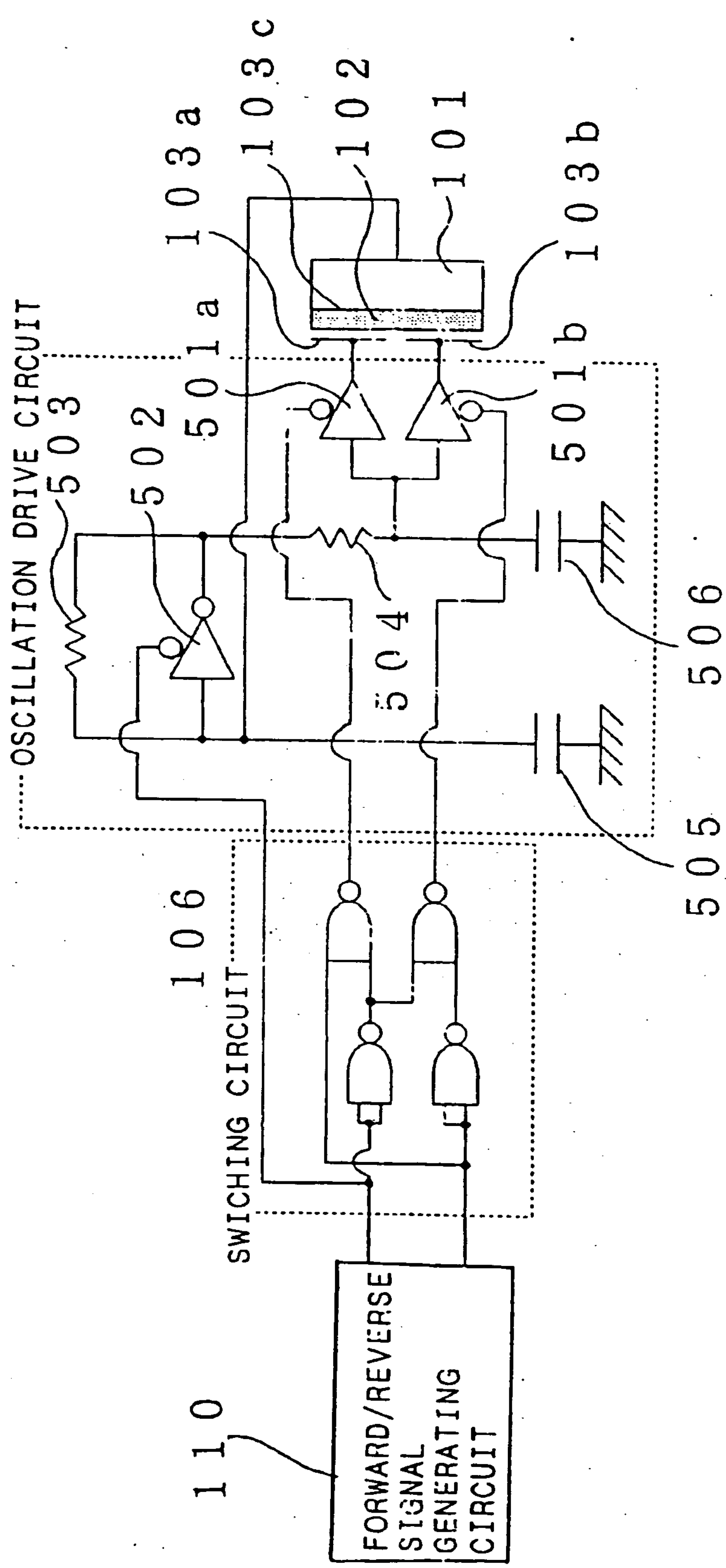

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FIG. 3

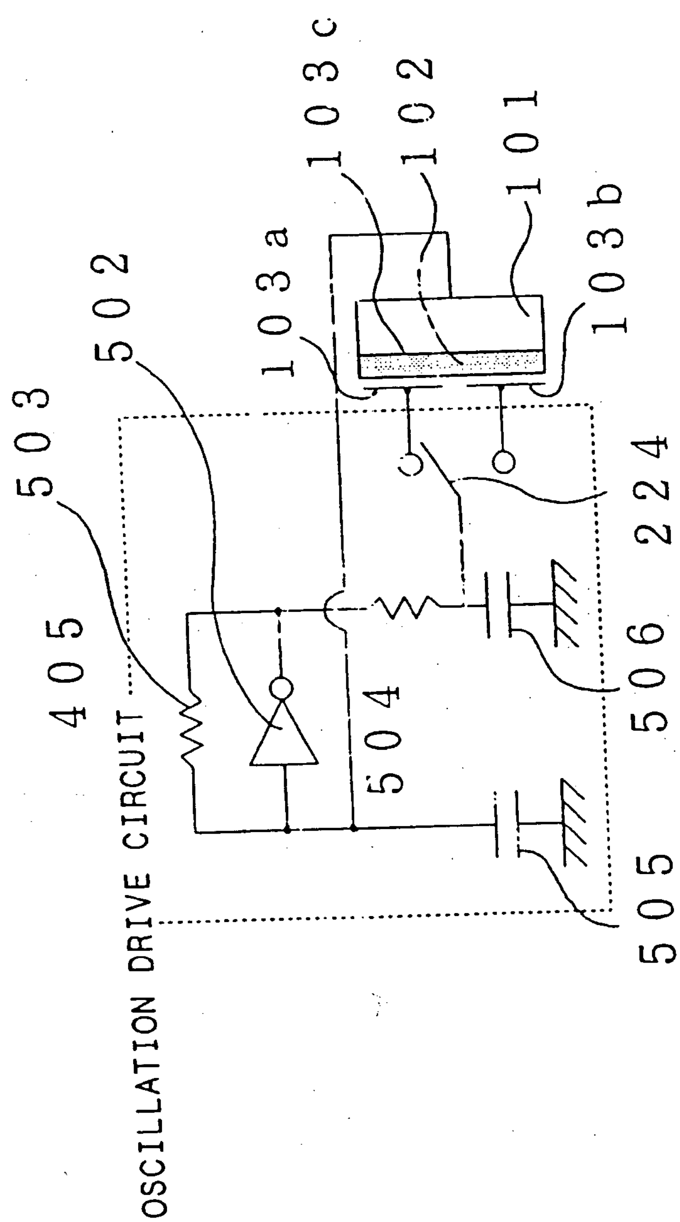

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FIG. 4

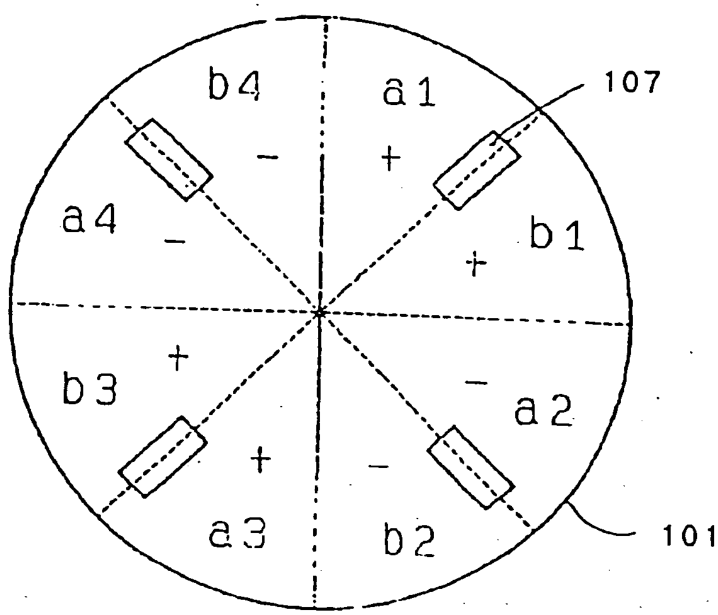

FIG. 5

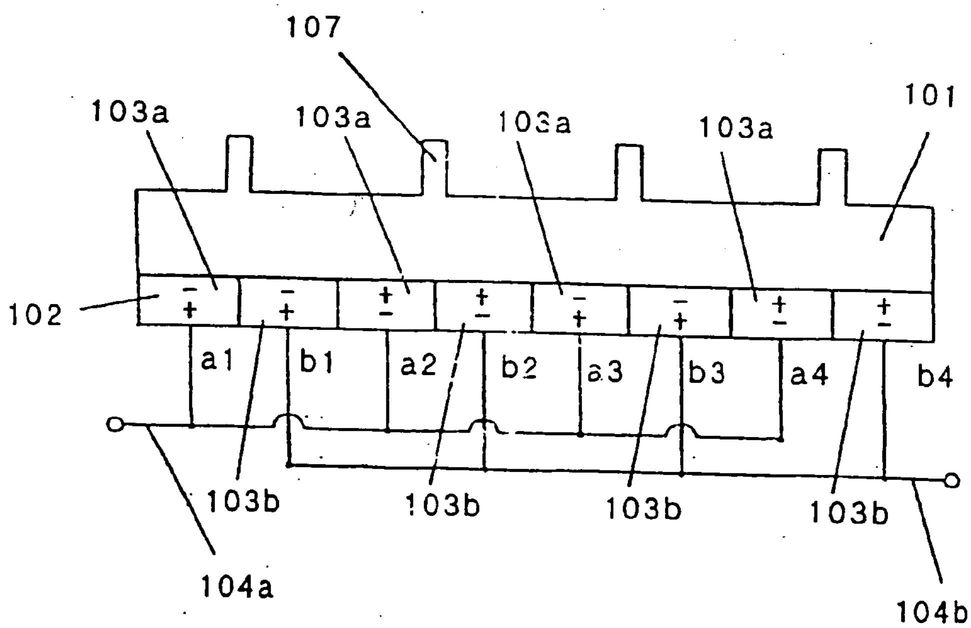

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FIG. 6

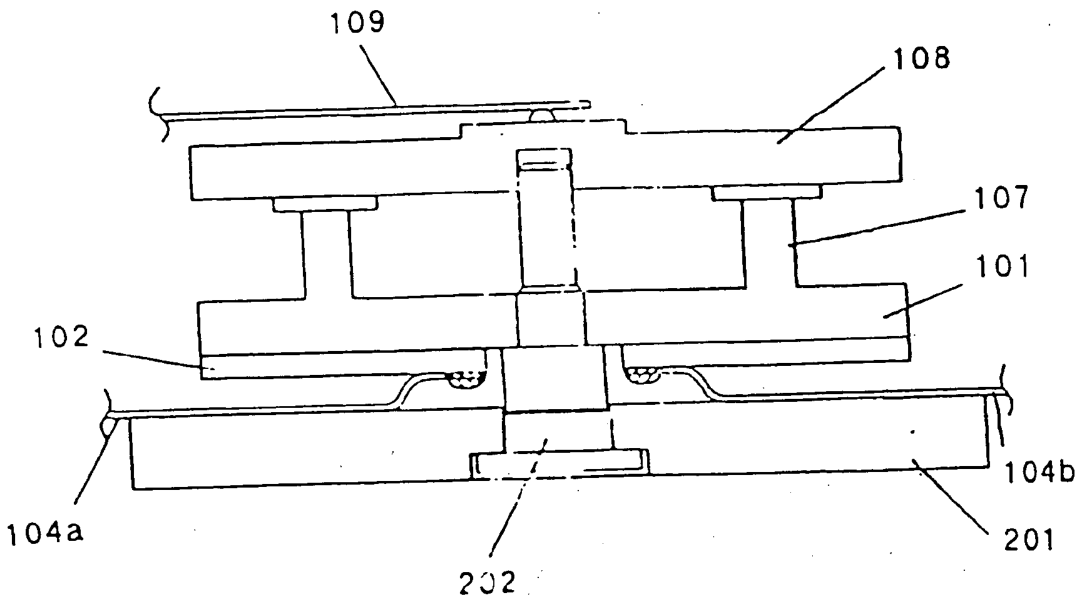

FIG. 7

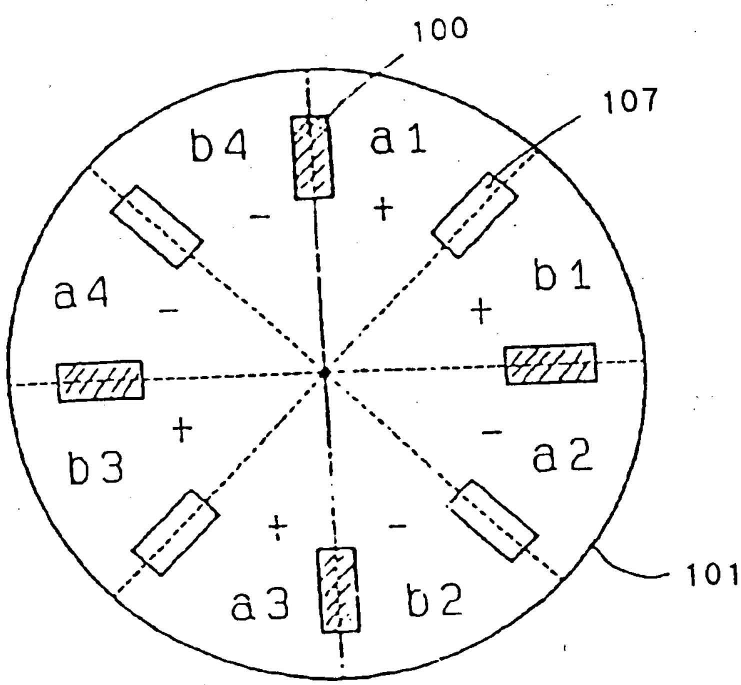

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FIG. 8

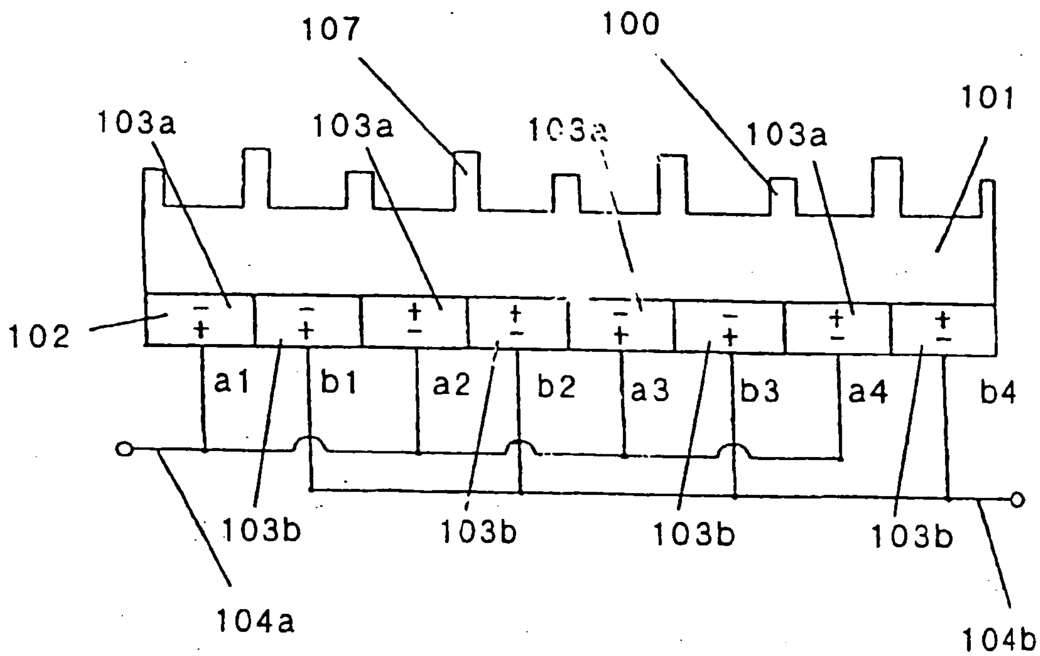

FIG. 9

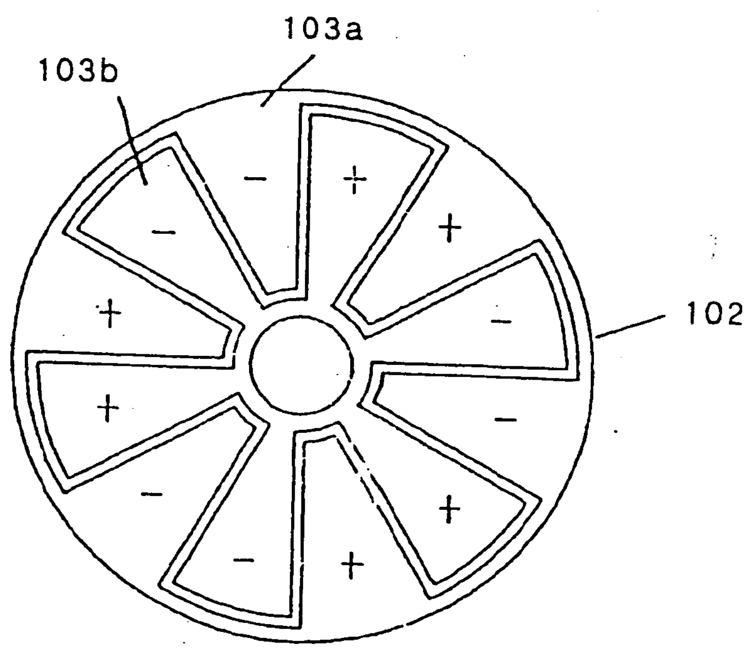

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FIG. 10

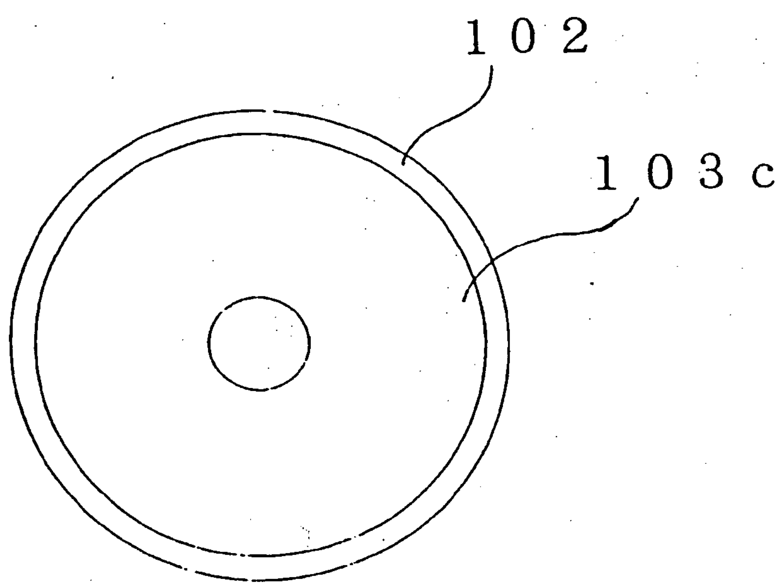

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FIG. 11

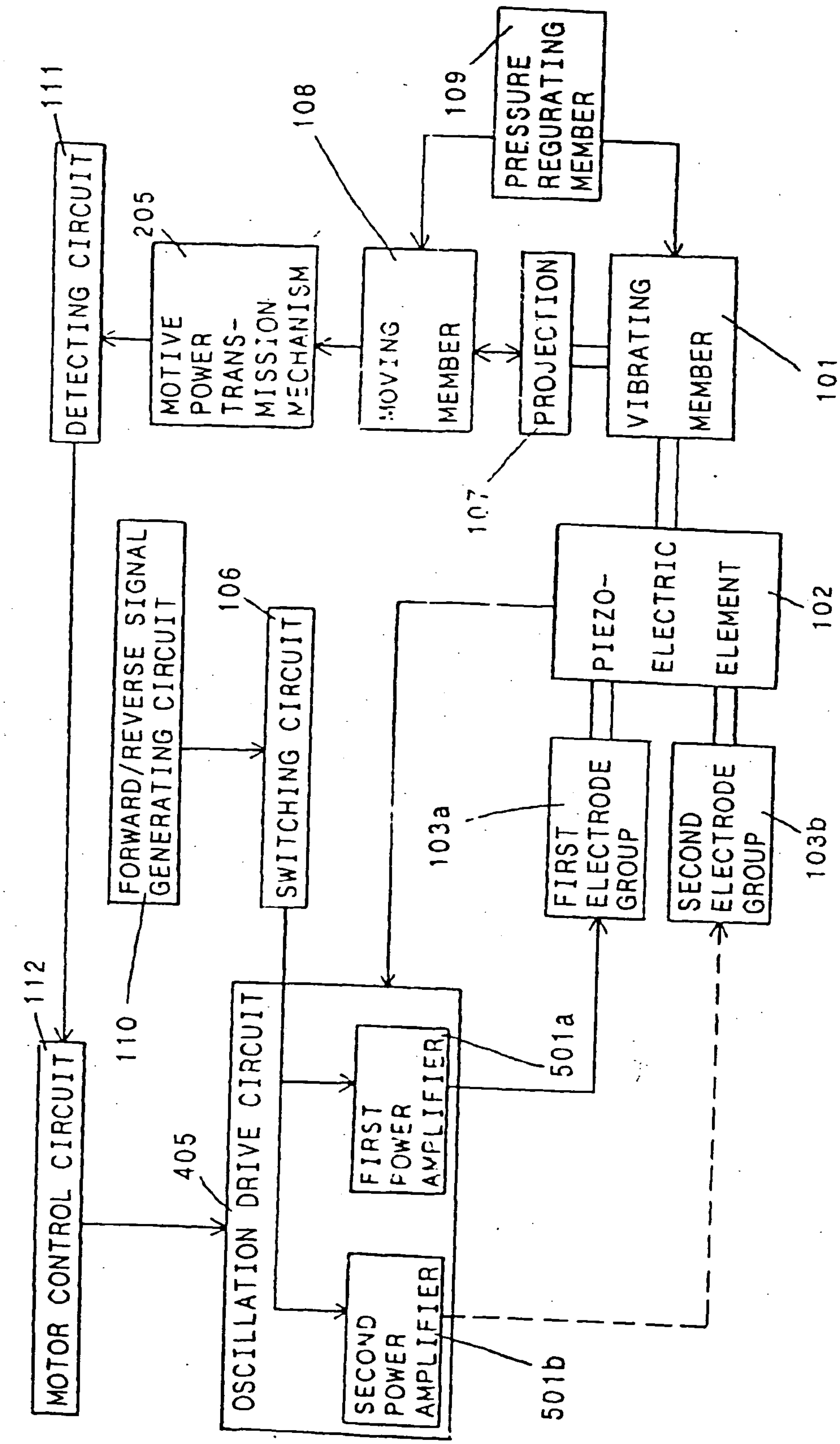

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FIG. 12

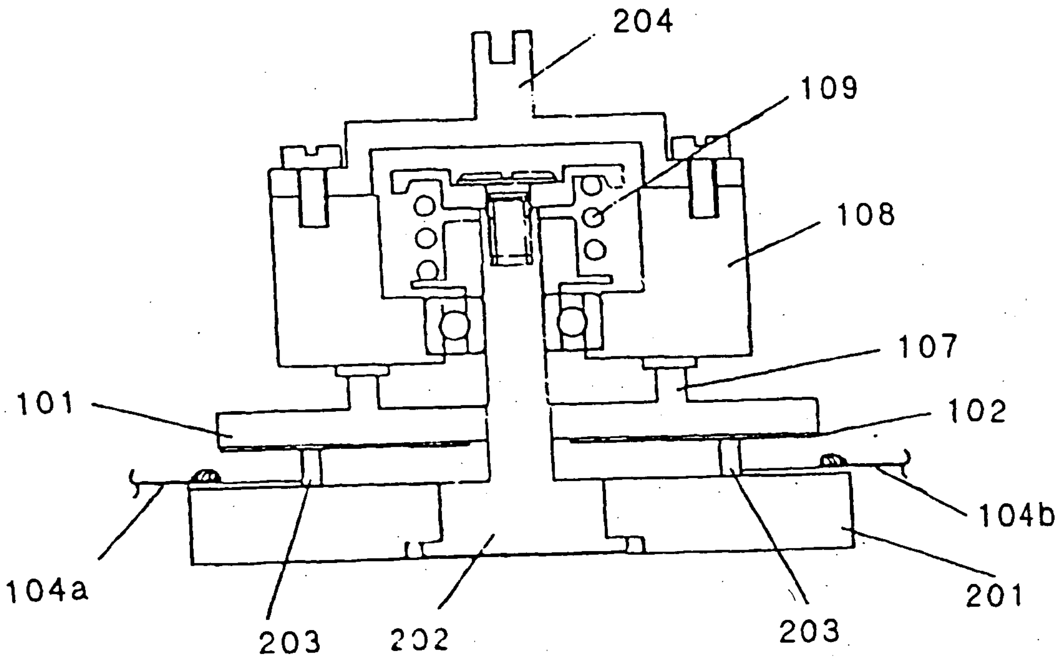
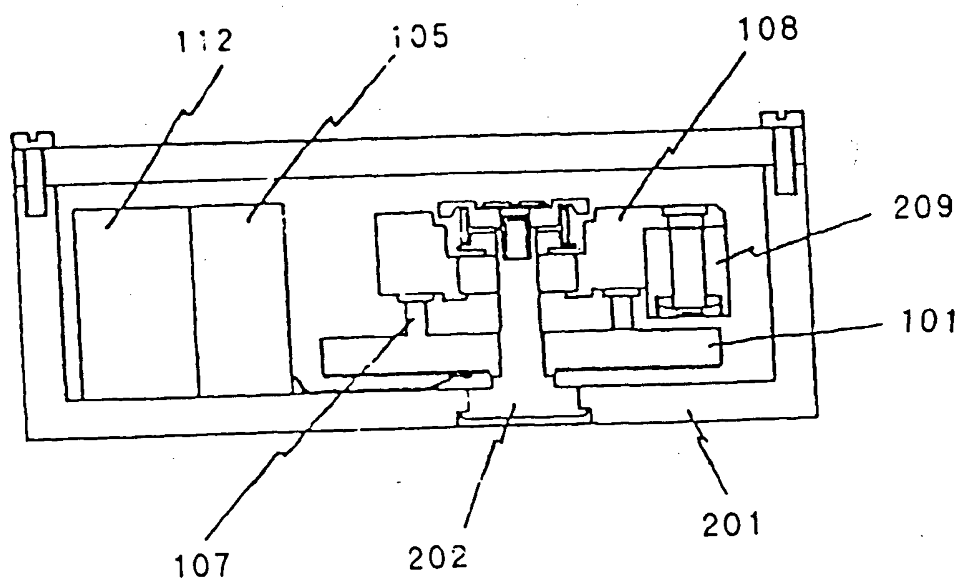


FIG. 13



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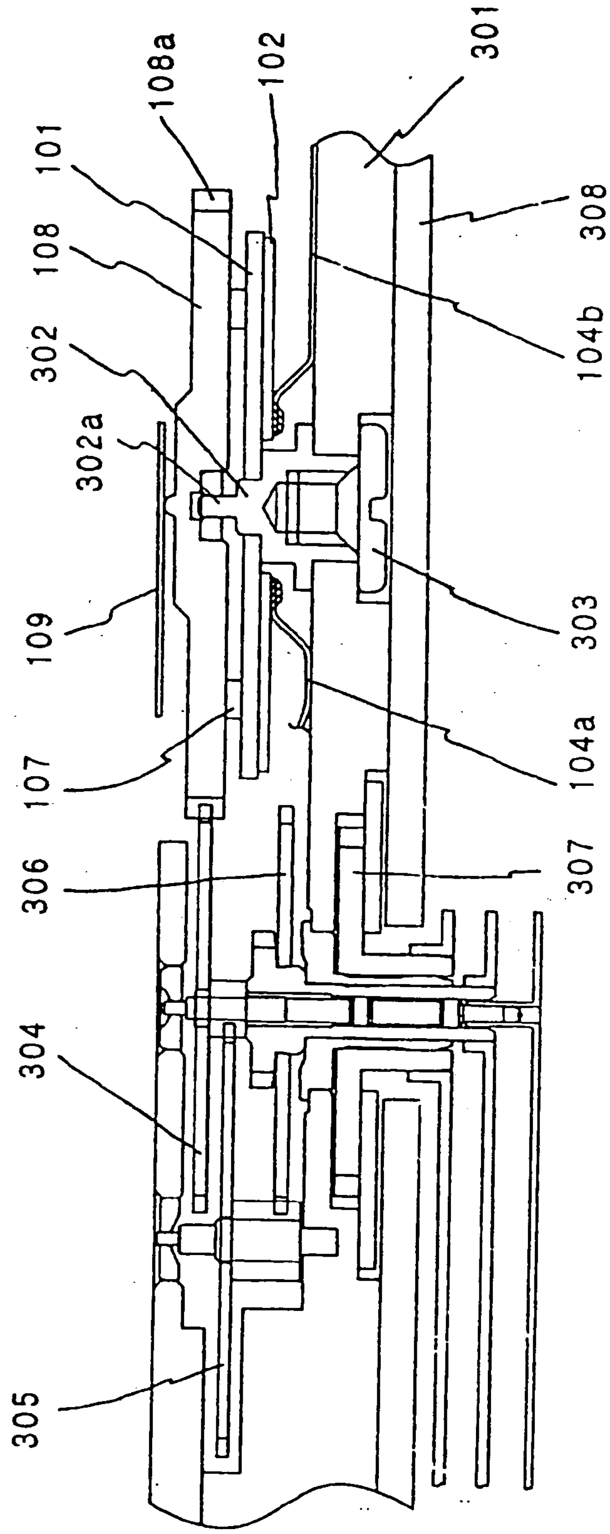

FIG. 14

BNSDOCID: <EP________0731514A1_I_>

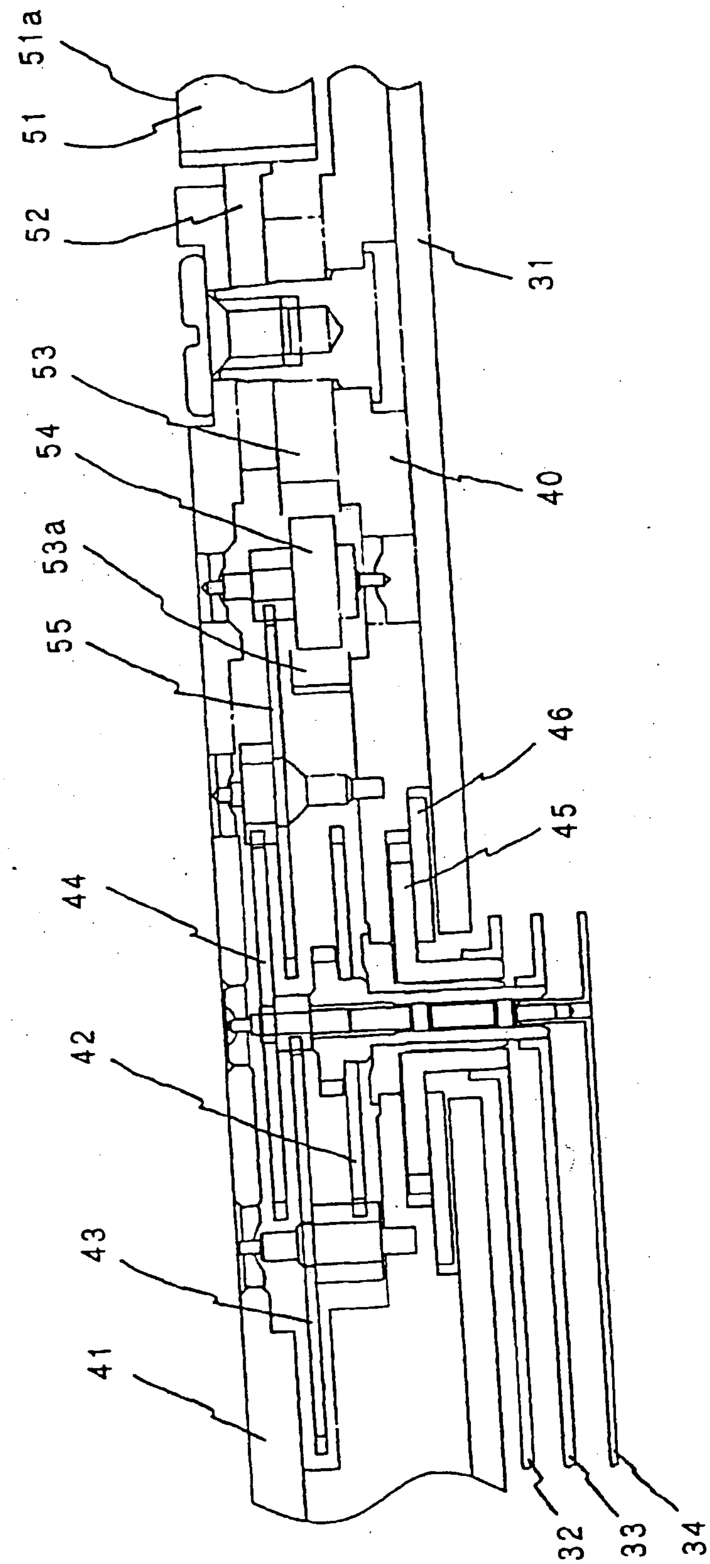

FIG. 15
PRIOR ART

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European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 96 30 1532

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	US-A-5 336 958 (SAYA DAISUKE ET AL) 9 August 1994 * abstract; figure 8 * ---	1	H01L41/04 H02N2/14
A	EP-A-0 562 817 (SEIKO INSTR INC) 29 September 1993 * abstract; figure 1 * ---	2	
P,X	EP-A-0 650 252 (SEIKO INSTR INC) 26 April 1995 * abstract; figure 11 * -----	1,2	

TECHNICAL FIELDS SEARCHED (Int.Cl.6)

H01L

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	21 June 1996	Pelsers, L

CATEGORY OF CITED DOCUMENTS

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